Determining the size of a total purchasing site to manage the financial risks of rare costly referrals: computer simulation model

Max O Bachmann, Gwyn Bevan

Abstract

***Objective*—To estimate the financial risks of 15 categories of rare costly referrals for total purchasing sites of different population sizes.**

***Design*—Computer simulation of 100 fund years assuming Poisson distribution of referrals.**

***Setting*—British general practices that have opted to become total purchasing sites. Referral rates and price estimates were supplied by South and West Devon Health Commission.**

***Main outcome measures*—Variation in referral costs to purchasers in relation to size of risk pool (person years at risk).**

***Results*—Random variation in referral costs increased as the size of the risk pool decreased. Variation increased greatly below 30 000 person years. The mean simulated cost of the referral categories considered was 2.8% of total NHS hospital and community service costs, and the maximum simulated cost for 7000 person years was 6.8%. Simulated variation was robust to assumptions about prices and referral rates for specific types of referral.**

***Conclusion*—Rare costly referrals seem unlikely to bankrupt total purchasing sites. The management of risk is not in itself justification for total purchasing to be based in several general practices in order to generate large populations. There are other ways of managing risk. Sites can easily explore options by simulations using local referral rates and prices.**

Introduction

Arrow's seminal paper on the distinctive characteristics of the economics of health care emphasised the problem of uncertainty and the consequence that institutional arrangements for financing health care are based on insurance.[1] The NHS reforms created two kinds of local insurers for hospital and community health services.[2] Health authorities are typically responsible for populations of over 250 000, and general practitioners can opt to become fundholders for their populations for a selected range of services, including some hospital services. Now general practices can opt to become total purchasing sites for all hospital and community health services, either as single practices or as groups of practices.

One aim of giving general practitioners budgets is to make them aware of the costs of their referrals.[3 4] For the budget to be effective it has to be designed to cope with risk from random variations in expenditure. One determinant of risk is the size of the risk pool expressed in person years: the product of the number of patients and the years over which expenditure has to be kept in line with the budgets. The larger the risk pool the lower the risk because the random variation is comparatively smaller. Managing risks by insurance, in which risks are shared with others, creates the intrinsic problem of moral hazard: insulating individual people from the problems of risk also removes economic incentives for them to be concerned about costs.[1]

There are several ways for total purchasing sites to manage risk. Several practices could join together to increase the size of the population covered; risks could be spread across several financial years, shared between a site and the health authority, or shared between different sites; and sites could use commercial insurers.

General practice fundholding incorporates three ways of managing risk. Firstly, eligible practices have to be larger than a specified size.

Secondly, practices can defer expenditures on elective inpatient admissions, which account for about 40% of fundholders' total budgets.[5-7] Additionally, practices are allowed to overspend their budgets by up to 5% in any given year.

Thirdly, there is also a "stop loss" arrangement, in which any referral costing more than £6000 has all of these costs paid for by the patient's health authority rather than the practice budget.

Early comments on the size of population that fundholding general practitioners would require to manage risk were based on the experience of health maintenance organisations in the United States. Scheffler observed that health maintenance organisations with fewer than 50 000 patients had difficulty surviving,[8] and Weiner and Ferris argued that a risk pool of only 11 000 patients might be unstable.[9] Crump *et al* examined the risk for fundholders using NHS data on rates and prices for 113 surgical procedures then included in fundholding.[10] Their simulations showed that practices of 9000 would exceed their surgical budget by at least 5% in 25 of the 100 years simulated, whereas practices of 24 000 would exceed their budget by this much only in about 5 of the 100 years simulated.

Small risk pools would thus be expected to result in significant overspending by fundholders. In 1992-3, however, only 5% of practices overspent their budgets by more than £100 000 (about 7% of the average practice budget of £1.5m).[7] Initially practices required populations of at least 11 000 to become fundholders.[2] This threshold has been successively lowered, and from April 1996 the minimum size was 5000 patients.[11] The introduction of total purchasing again raises the question of how large sites should be. Because health maintenance organisations cover all services, Scheffler's observation may be a more appropriate guide to the size of total purchasing sites than the experience of general practice fundholding.[8]

We considered random variation in expenditure caused by rare and costly referrals. We used data on average costs and rates for a selected group of rare costly admissions to examine the influence of the size of the risk pool on random variation in expenditure. We also examined the impact of variations in rates of referral and in hospital prices. Total purchasing is dependent on local arrangements between practices and health authorities, and we used local data to show how those

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Table 1—*Estimated referral rates and prices used in simulation, with contribution of each type of referral to total expected cost*

Referral category	Rate: No of referrals per 100 000 population per year	Price: Mean cost per referral (£)	Expected cost per 100 000 person years (£) (rate × price)*	Cost as % of expected total cost
Special care baby unit	37.5	6737	252638	21
Forensic psychiatry (closed ward)	5.1	32000	163200	14
Tertiary psychiatry	3.4	40000	136000	12
Forensic psychiatry (open ward)	1.7	70000	119000	10
Coronary artery bypass grafting	21.5	5265	113198	10
Rehabilitation after brain injury	1.7	52000	88400	7
Peritoneal dialysis	7.5	9664	72480	6
Cardiothoracic surgery	10.0	6583	65830	6
Emergency spinal surgery	2.6	20000	52000	4
Heart valve operation	4.8	7500	36000	3
Child psychiatry	6.1	5072	30939	3
Bone marrow transplantation	0.9	20565	18509	2
Renal transplantation	2.6	6809	17703	2
Home dialysis	0.7	10093	7065	1
Major heart operation	1.0	7018	7018	1

*Total = £1179979.

responsible for developing total purchasing in any site could simulate their risks with a standard spreadsheet package on a personal computer for the rare costly admissions that concern them. This method could also be used to examine risks from rare and costly prescriptions of drugs, such as growth hormone.

Methods

Financial risk due to random variations in 15 categories of rare costly referrals was simulated over 100 fund years for various sizes of risk pool expressed in person years. The categories of referral considered are shown in table 1. These categories were chosen by South and West Devon Health Commission when examining risks for its total purchasing sites. They are similar to, although not as comprehensive as, services purchased by the West Midlands Regional Specialties Agency.[12] Data on rates and costs of the referrals were supplied by the health commission.

Numbers of referrals were simulated on an Excel spreadsheet, using the random number generation tool and assuming Poisson distributions.[13] The total cost of the 15 referral categories for each year was calculated by summing the products of the simulated number of each type of referral and the respective hospital price. These costs were expressed in absolute terms, as percentages of the expected cost of rare costly admissions and as percentages of the total purchasing budget. The expected cost was defined as the sum of the products of prices, rates, and risk pool sizes. The total purchasing budget was defined as the product of the population size and the cost per head of hospital and community health services in the NHS in 1994 (£430)—that is, the distinction between standard fundholding and total purchasing was not considered.[14] The variation in costs was defined as in the paper by Crump *et al* as the difference between the 95th and 5th centiles expressed as a percentage of the mean simulated cost[10]; this measure is more appropriate for Poisson distributions than is the coefficient of variation.

A sensitivity analysis was conducted for a risk pool of 30 000 patients to see how sensitive the simulated variations in total costs were to the assumed rates and prices for each referral category (the base rates and prices in table 1). Hospitals' prices for specific types of admission range between 50% and 150% of the mean price[15] and general practitioners' referral rates between about 50% and 200% of the mean rate.[16] Simulation was thus repeated four times for each referral category: using a price 50% of the base price, a price 150% of the base price, a rate 50% of the base rate, and a rate 200% of the base rate. For each simulation only one price or rate for one referral category was changed at a time, all other rates and prices being as in table 1.

The annual premiums required to be paid by total purchasing sites for different stop loss arrangements were simulated by examining referrals priced above each amount. We considered stop loss amounts of £6000 (the current amount for standard fundholding), £10 000, and £30 000.

Results

The distributions of costs simulated over 100 years are shown in table 2. As expected, the degree of random variation decreased as the population increased. A risk pool of 7000 had a comparatively high degree of risk, which decreased appreciably with a risk pool of 30 000, with diminishing marginal returns above this size (summarised as variation in table 2). Mean simulated costs were similar to expected costs (table 2), supporting the validity of the simulation.

The financial risk may also be expressed as another statistic: the discrepancy between simulated and expected costs of rare costly admissions as a percentage of expected costs. Distributions of these statistics are shown in figure 1. The degree of random variation in year to year costs is represented by the intercentile spread. For example, the costs in 90% of simulated years lie between the 5th and 95th centiles. As in table 2, the risk due to random variation increased rapidly with risk pools of under 30 000 patient years. The dotted lines show that for the 95th most costly year to be within 50% of the expected cost, a risk pool of at least 30 000 would be required. For a total purchasing site without an insurance pool to be almost certain of being

Table 2—*Distributions of referral costs (£) for different sizes of risk pool (No of person years at risk) simulated over 100 years*

	No of person years at risk						
	7000	10000	30000	50000	70000	100000	1000000
Centile of referral cost:							
5	26931	44372	210518	383192	630793	887486	10980380
25	50039	76343	294635	528232	709340	1074556	11453914
50	75178	108482	351213	591404	799892	1184946	11926911
75	111905	157257	429880	691266	902103	1287445	12162928
95	173561	237623	524032	809582	1073450	1439343	12656710
Expected cost*	82449	117784	353352	588920	824488	1179979	11778400
Mean simulated cost	83582	120166	360574	601671	818628	1181496	11856702
Variation in simulated cost (%)†	175	161	87	71	54	47	14

*Rate × person years × price.
†(95th centile–5th centile)/mean simulated cost.

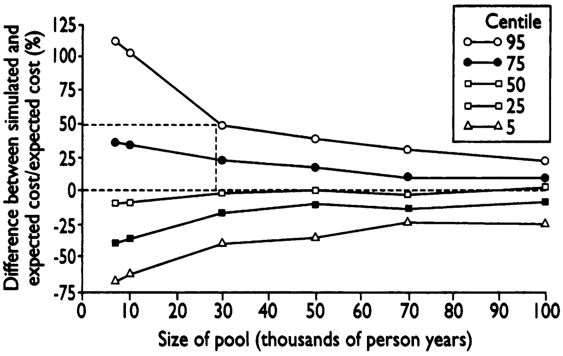

Fig 1—*Distributions of differences between simulated and expected referral costs as percentage of expected cost for different sizes of risk pool*

able to keep within its rare costly admissions budget it would need a contingency reserve. For example, to be 95% certain of being able to cover the cost with a risk pool of 7000 patient years the rare costly admissions budget would have to be 2.1 times the expected value, while with 1 000 000 it would have to be only 1.07 times higher (calculated from table 2).

The sensitivity analysis showed that the simulated variations in costs were robust to the assumed rates or prices of any particular referral category. In the basic analysis for a risk pool of 30 000 the variation (defined in Methods) was 87% (table 2). In the sensitivity analysis the smallest variation was 75% (obtained when the price of referral to an open ward for forensic psychiatry was halved) and the greatest was 103% (obtained when the price of a referal to a special care baby unit was doubled). Of the 60 sensitivity analyses carried out (four for each referral category, as described in Methods), 30 produced variations between 80% and 90%. The mean simulated costs were most sensitive to assumptions about the rates and prices of special care baby units and psychiatric and forensic psychiatry; this would be expected because these categories make the greatest contribution to the expected cost (table 1). If the rate of referrals to special care baby units was doubled, then in the 95th most costly year these 15 rare costly referrals would cost 22% more than expected; all other sensitivity analyses produced smaller overspends than this.

When expressed as a percentage of the total purchasing budget, the mean costs for all 15 rare costly referral categories were between 2.7% and 2.8%, regardless of fund size. If an insurance fund covering the 15 rare costly admissions categories were created, the premium should thus be about 2.8% of the total purchasing allocation, with modification depending on the stop loss amount, changes over time in referral rates and prices, and administrative costs. The 95th most costly years for funds with risk pools of patient years of 7000, 10 000 30000, 50 000 70000, 100000, and 1 000000 cost 5.8%, 5.5%, 4.1%, 3.8%, 3.6%, 3.3%, and 2.7% of total allocation, respectively. The greatest simulated cost for the smallest risk pool—that is, the 100th centile for 7000 patient years—was 6.8% of the total purchasing budget—that is, 4.0% more than the mean simulated cost. For a risk pool of 10 000 patient years and for stop loss amounts of £6000, £10 000, and £25 000 the annual premiums should be 2.5%, 1.4%, and 1.2% of the total purchasing budget, respectively.

Discussion

This simulation shows that even small total purchasing sites are unlikely to be bankrupted by these 15 types of rare costly admissions. This conclusion would not be altered if more referral categories had been considered. Increasing the number of referral categories covered would reduce the key problem of managing risk—that is, random variation in cost in relation to expected spend on rare costly referrals. Random variation in costs would decrease because inclusion of more such categories increases the chance that they balance each other. A small total purchasing site, for example, is highly unlikely to require an admission to forensic psychiatry and for renal transplantation and rehabilitation after brain injury in the same year (this combination only occurred in one of 100 simulated years for a risk pool of 7000). This partly explains why the variation obtained for 133 surgical referral categories by Crump *et al*[10] is smaller than the variation obtained for only 15 categories in this exercise (table 2).

UNCERTAINTY ABOUT RATES AND PRICES

There are intrinsic uncertainties about referral rates and prices for the rarest and most costly admissions. For example, the price of an admission for forensic psychiatry is likely to vary with the length of stay, which is difficult to predict in advance, and the rate estimates are likely to be unstable even when based on district populations. Sensitivity analysis has shown, however, that our main findings are robust to changes in rates of referral and prices charged. The main vulnerability to overspending is due to the comparatively high volume of neonatal special care and to costly forensic and tertiary psychiatry.

In any specific total purchasing site the risk from rare costly admissions will be different because of differences in rates and prices. Anyone with a personal computer and a spreadsheet with a random number generator can estimate risks using local information. When accurate information is lacking, a variety of estimates can be simulated to examine the implications of uncertainty about rates and prices and thus help identify which information is most important. Any putative arrangements can thus be assessed using the methods we have described in this paper. For specific examination of recurrence of referrals in individual patients, a negative binomial distribution may be more appropriate than a Poisson distribution,[17] but this was not of central importance to the referral categories considered here.

EFFECTIVE RISK MANAGEMENT

Our analysis suggests that total purchasing sites ought not to begin by aiming to be large for the purpose of reducing risk. Instead the focus ought to be on how to achieve a common purpose within each site: in agreeing contracts and managing spend against budgets. Having come to a view of the best working arrangements, a site can explore what, if any, extra arrangements might be needed to manage risk.

Key messages

- The smaller the risk pool (the number of patients and years over which expenditure has to balance with budgets) the greater the financial risk due to rare costly referrals
- Insurance arrangements for most risks ought to be organised to extend each practice's risk pool by giving it more years over which to pay
- Risk pools of at least 30 000 patient years should be created: a total purchasing practice of 10 000 patients ought to seek at least three years to manage its expenditure
- Financial risk due to rare costly referrals may easily be modelled if local referral rates and prices are available
- Special arrangements are needed for catastrophic insurance for rare and costly hospital care over which general practitioners have little discretion

The appropriate way of increasing a risk pool is to extend it over time to enable a site to have a number of years to pay back any overspends. For other sites to take on this risk creates a problem of moral hazard. It undermines the underlying rationale of giving practices budgets, which is that they are responsible for the economic consequences of their decisions.

Exceptional catastrophic risks—for example, forensic psychiatry—do not naturally form part of practice budgets. These risks ought to be shared with health authorities and financed by a general levy, with payments authorised by a committee representing contributors. In general, therefore, our analysis supports basing total purchasing sites on single practices. We are interested to see whether experience with total purchasing bears this out.

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Commentary: Models can be powerful tools for making decisions about effective and efficient health care

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Max O Bachmann and Gwyn Bevan explain a method for making informed decisions about the size of a total purchasing site to manage the risks of rare costly referrals. A randomised controlled trial is clearly not practicable for obtaining the necessary information. They suppose that the occurrence of rare referrals can be mimicked by a mathematical model called a Poisson process. The key assumptions that point to a Poisson process are that rare referrals occur at random and that such referrals are independent within each category and between categories. The assumption of independence seems reasonable for the categories selected, so the chosen mathematical model for describing the referrals is reasonable. This mathematical model does not cover dependent referrals—for example, for infection, which increases the risk of further referrals in the area served by a general practice.

Bachmann and Bevan simulated referrals and calculated the resulting cost with the help of a standard program on a computer. Computer simulations are often but not always needed for obtaining information from mathematical models for health care. Some models are simple enough to be solved through a combination of mathematical and numerical analysis. Complex models require careful simulations. A Poisson process is a simple model and the information on cost that is required is the sum of the costs of the various types of referrals. The data of Bachmann and Bevan suggest that the variation in the total cost can be predicted analytically without using a computer simulation. People who are not mathematicians may find it easier to accept results from a computer simulation rather than the results that follow from a combination of mathematical and numerical analysis. Table 1 shows the predictions obtained from mathematical and numerical analysis, together with the results of the simulation of Bachmann and Bevan for 100 000 person years. The results are similar, which corroborates the simulation.

Table 1—*Distributions of referral costs for 100 000 person years at risk through mathematical analysis and computer simulation*

	Centile of referral cost					
	5	25	50	75	95	Variation
Mathematical prediction	897331	1062898	1177979	129306	1458626	48
Simulation*	887486	1074556	1184946	1287445	1439343	47

*See table 2 of Bachmann and Bevan.

The structure of models permits rational use of data from various sources, including randomised controlled trials.[1] The common problem of unreliable data may be handled by a careful sensitivity analysis, and Bachmann and Bevan considered errors in referral rates and costs. Modern computers can solve quite detailed models, and these models can be linked to patient data collection systems in general practice. Evaluating and monitoring care for a particular disease—for example, asthma—or predicting the use of resources for a defined group are two of the many possible benefits that can be obtained from models.[2 3]

The particular example of the assessment of financial risk illustrates a general point that appropriate models are powerful tools for making informed decisions about effective and efficient health care.

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